VENTILATION

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Extracts from a Paper on

"HOSPITAL CONSTRUCTION"

read by

DR. JOHN W. HAYWARD

before the

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on

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VENTILATION.

BY

DR. JOHN W. HAYWARD.

"THE best of all disinfectants and germicides, as well as of tonics and restoratives, being fresh air and sunshine, provision should be made for the admission into the wards and the whole hospital of as much of these as possible—abundance of fresh air without draughts and of sunshine without scorching.

"This plan serves very well in climates where the air is always sufficiently warm to be admitted directly into the wards through open windows, but it is very ill suited for climates like that of Great Britain, where during at least eight months in the year, the air has to be warmed before it can be admitted, at least in sufficient quantity to meet all the necessities of the ward, that is, for efficient ventilation. Nor is cross ventilation necessary in our climate, for in summer open windows on one side of the ward will admit all the air required for ample ventilation, when there is perceptible movement of the outer air; and in winter open windows cannot be borne, at any rate, in hospitals for consumptives.

Open Fire Ventilation.

"It would indeed be well to have even small wards warmed by pipes, because of the many objections to open fires.*

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* "For hospital wards open fires are risky, costly, and troublesome; they greatly embarrass all plans of ventilation, and are in many other ways objectionable—they radiate heat only from isolated and distant centres, and cannot warm wards at all equably; they are noisy, and dusty, and require frequent attendance, and this disturbs the patients' sleep and rest; besides the warmth they supply varies with the nurses' attendance to them, and is sometimes much, sometimes little.

"They are of but little use as means of ventilation; they certainly abstract air, but they take it principally from near the floor, whereas the foul air accumulates near the ceiling, being heated and so made light by the same means that foul it.

"Special provision should be made for the admission of abundance of fresh air at all times in winter as well as summer, at night as well as in the day time, and in both wards and corridors. 'Another great cause of the mortality in hospitals,' says the writer in the 'Encyclopædia,' 'is the want of efficient ventilation' (*loc. cit.*). By 'ventilation' is meant the continuous removal of the air that has been used, and the replacing of it with fresh air that has not been just used.

Open Window Ventilation.

"For winter, and for spring and autumn, the outer air in our climate being generally too cold

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"Hospitals warmed only by open fires are sure to be very imperfectly warmed: and if at the same time they are attempted to be ventilated only by open windows they are most certainly also very imperfectly ventilated. It is much to be regretted that some hospitals are professed to be ventilated and warmed by simply open windows, and open fires, even throughout the winter in this climate.

"In a Blue Book, issued in 1898, 'On the Ventilation and Warming of Board Schools,' on p. 23, occurs this statement, in reference to ventilation by open windows:—'In those cases in which the ventilation was effective the temperature of the dormitory would follow closely that of the outside air, and would not exceed that of the outside air by more than about 2½ deg.'

to be admitted through open windows, it must be let into the wards out of the corridors, where it is warm. It is, of course, impossible to warm the air as it enters, before it impinges on the patients, when it is let in through open windows and the warming is done by open fires, because the patients lie between its entrance and the means of warming.

"With reference to winter ventilation, the writer in the 'Encyclopædia' says :—'The fresh air should be brought in at the lowest part of the ward.'

"The corridors should be supplied with fresh air in such quantity as to cause the air to move into the wards whenever the doors are opened; this will tend to prevent the air of the wards spreading throughout the hospital every time the doors are opened; letting the air in through the windows tends to drive the air of the wards into the hospital, which is always objectionable; and is also risky when there is infectious disease in the wards.

Removal of the Foul Air.

"So much for the supplying of fresh air; what about the removing of the foul?

"The air of the wards, after having been used, should be abstracted and replaced with fresh.

"How shall this be done?

"In summer, in the daytime at any rate, it is not difficult of accomplishment by open windows alone, when there is sufficient movement of the outer air, as the windows can be opened to almost any extent; nor is it difficult in winter by the fires alone, when these are burning, as each fire takes away 600 cubic feet of air every minute.* In spring and autumn, however, it is somewhat difficult to accomplish satisfactorily, because the weather is then generally too cold to have the windows always open and yet not cold enough to have the fires continually burning, so that the abstraction cannot then be accomplished efficiently by either windows or fires; it must consequently be done by outlets specially provided for the purpose.

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* "Unfortunately the air taken away by the fires is mainly taken from below the patient, whilst the foul air is above him; it is therefore disadvantageous rather than otherwise, as it diverts from him the air that is tolerably fresh and leaves to him that which has been fouled; in hospital wards and other inhabited rooms the air near the floor is always less impure than that near the ceiling, because the same means that cause it to rise also foul it.

"For this and several other reasons, it is desirable that the fires shall not be used as ventilators, but shall themselves in all instances be supplied from a special and independent source, as recommended by the Government Commissioners.

"In hospitals constructed on the plan here advocated this could easily be done by flues from the fresh air chambers, terminating at sides of the grate near the floor, one on each side; their terminal ends being closeable by hit-and-miss gratings to regulate the supply, and their mouths by well-fitting valves to close them entirely when the fires are not in use.

"'The foul air,' says the writer in the 'Encyclopædia,' 'should be taken out at the highest part of the ward.'* These outlets should then be in the wards, in or near their ceilings; and the best place for them is by the chimney breast, to lead into flues run up the chimney stack by the side of the smoke flue, as the Government Commissioners point out. There must be a separate flue from each ward, they should lead straight to the outer air, and be capped by a Boyle's abstractor.

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* "'While the air is in the lungs,' say the Government Commissioners, 'it acquires so much heat that it becomes specifically lighter than the surrounding air, and rises above our heads; . . . the heated air which passes upwards should pass away. . . . For the ventilation of rooms exits should be provided for the spent air near the ceiling.'

Abstracting the Foul Air near the Floor.

"To the plan of abstracting the foul air near the floor, there are at least four grave objections:

"(1) It is opposed to Nature's law of atmospheric pressure, and therefore requires the use of special abstracting power by means of furnaces for its accomplishment.

"(2) By drawing down the foul air it causes it to be breathed over again, which recently breathed air ought never to be.

"(3) The fresh air supplied is apt to be forced in over-heated, in fact burnt, and so made unhealthy.

"(4) The long tortuous flues cannot be kept clean, and will therefore become lurking places for dust and germs.

"The plan is quite unsuitable for hospitals, and should certainly never be used where there is likely to be infection. Besides, it is also open to the same objections as ventilation by open fires, viz., that it tends to draw away the air of the lower part of the ward where it is always the least impure.

"Moreover, the slight tendency of the thin layer of air in contact with the outer walls to fall downwards, is no demonstration that the mass of foul air over the centre of the ward should be attempted to be drawn down, in order that it may be taken out at the bottom. 'The method of low ventilation,' say the Government Commissioners, 'should be avoided on various grounds. . . . The heated air which passes upwards, should pass away.' (Blue Book, pp. 4—bottom—and 30.) The plan certainly economises warmth, but it does so only at the expense of the ventilation, that is by the heated foul air not getting away.*

Position of Fresh Air Inlets.

"But the abstraction of the foul air cannot be effected by either low or high ventilation,

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* "It is a very mistaken notion that, because cold carbonic acid gas is heavier than atmospheric air, therefore carbonic acid is always to be found near the floor; in occupied rooms and hospital wards it is not cold but warm and therefore light, and with the other warm gases, rises towards the ceiling; besides, carbonic acid is not the only deleterious impurity.

"There are other more dangerous impurities, all of which, as well as the carbonic acid, are carried upwards along with the heated air. (Blue Book, p. 98.) Moreover, in an occupied room, with lights and a fire, the temperature of the air near the ceiling is generally unless at the same time an equivalent quantity of fresh air is being continuously supplied.

"How shall this supply be procured?

"Of course, as it cannot in winter be through the ward windows, it will have to be out of the corridors, and the corridors will have to be supplied with an equivalent quantity; and as this cannot be through their own windows, because that would let in cold air, its entrance will have to be provided for otherwise. The best, and perhaps the only feasible way, is that it shall be let in through the basement and allowed to pass up through gratings in the corridor floors, along the sides of the whole length of the corridors; it can be then let into the wards either by special openings through the wall or by the doorway, as already mentioned.

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over 65 deg. F., so that air forced in below to rise above it and press it down towards the skirting abstraction flues must be forced in at or above 70 deg. F.; and so heated, it is unhealthy, because burnt.

"Except the thin layer against the windows and outside walls, there is no tendency for the foul air to fall downwards, neither is it an easy matter to draw it down to the skirting board outlets; it requires, indeed, strong and costly furnace power to do it. This plan of downward ventilation should never be used for hospitals, nor for anywhere else where there is heated foul air or infectious disease. (See 'Health and Comfort,' pp. 10 - top - 26, 27—bottom.)

"Now, inasmuch as in the foregoing arrangement, the foul air flues pass directly from the wards to the outer air, fear may be entertained that the outer air will pass down them into the wards just as it will pass into the wards through open windows. The cases are, however, not parallel; windows afford merely cold openings, whereas the special outlets are tapering tubes, and are somewhat warm. Besides, open windows do not always let in the outer air; in cross ventilation the open windows on the leeward side of the ward act as outlets; when open windows on one side act as inlets, those on the opposite side must act as outlets.

"The flues, too, being at a higher level and warm, and, the air at their mouths being warmer than that entering by the inlets, they must act as outlets; and particularly if the flues themselves are large at the bottom and small at the top like factory chimneys, and there is—as there should be—also continuous ample supply of cooler air flowing into the wards at a lower level; practically this is found to be the case.

"Nevertheless, the mouths of the flues in the ward ceilings should be provided with valves, as a safety against adverse circumstances; and their terminal ends outside may be protected by Boyle's air pump ventilators, which, as well as the last length of the outlet flue, must have an area equal to only 4 in. square, for each single-bed ward, and must reach somewhat higher than the smoke flues.*

"By the foregoing arrangements the whole hospital and every individual ward will be efficiently ventilated all the year round, with cool air in summer and warm in winter, almost automatically; and without labour or cost, except for the warming furnaces; and with both ventilation and warming completely under control.

Natural Ventilation.

"That efficient hospital ventilation can ever be automatic and costless may, perhaps, appear really absurd; it is, however, not so absurd as it may appear. This will be evident by reference to the natural laws of atmospheric pressure and of its expansion by heat. In fact, the idea that the atmosphere cannot be caused to pass through a hospital or other building at a rate of emptying and replenishing every twenty minutes, by having the inside warm and the outside cold, with sufficient openings at the bottom and top, is itself absurd to anyone familiar with dynamics.

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* "It is essential that the outlet flues have a much less area at the terminal end than at the mouth, and that the mouth be able to be closed entirely or opened to the full extent—not to be closed by grating, but by shutter. Boyle's Air Pump Ventilators are not only very effective preventers of down-draught, they are also real producers of up-draught, in consequence of the movements of the atmosphere forming a vacuum.

"The real questions are:

"(1) Can its passage be controlled and regulated to the average of twenty minutes?

"(2) Can it be so warmed that the occupants will not feel it as an unpleasant current or draught?

"Both these questions may be answered in the affirmative.

The Laws of Atmospheric Pressure.

"In the scheme here propounded, indeed, the automatic and nearly costless character, and its appropriateness to hospitals, follow of necessity from *advantage being taken of the laws of atmospheric pressure, and providing openings and flues and means of warming and cooling so as to meet the requirements of the laws.*

"Here is the pivot, the cause of success, in particular the openings and flues and the means of warming the incoming air. Without these, the arrangement would not act efficiently; with them it is an unequivocal and unqualified success; the air inside the hospital being warm and light, and that outside being cool and relatively heavy; the heavy air entering at the basement and the light air escaping at the roof, the outside air presses in through the inlets and the inside air presses out through the outlets at a speed determined by the difference in weight; that is, in winter, a difference between air averaging about 35 deg. F., or lower, and about 65 deg. F., or higher.

"Now, according to the laws of atmospheric pressure, this difference produces a speed of at least 8 ft. per second, in ordinary flues or chimneys. (See Blue Book, p. 6, and 'Health and Comfort,' p. 26; also p. 106, where illustrations are given.)* In the hospital flues the speed will be increased by the vacuum produced by the Boyle's abstractors fixed on their terminal ends, and would be further increased by a gas light in their lower ends, perhaps together to 12 ft. or 16 ft. per second; that is, if the air had to pass only through flues; it has, however, to pass through the hospital:—entering at the basement inlets, it has to pass up between the warming pipes and through the gratings in the corridor floors; the obstruction offered by these impediments will reduce the speed perhaps one third; but even if it reduced it one half: that is, to only 6 ft. per second, this would be an excessive and

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* " 'The ventilation of rooms and buildings,' say the Government Commissioners, 'depends in a great measure upon the ascending and descending currents of air caused by the difference in temperature, the warmer air ascending and the colder and heavier descending; the greater the difference of temperature the greater being the difference of weight and of the rapidity of interchange. . . A cubic foot of air—

at 30 deg. F., weighs	...	569·2 grains
at 70 deg. F., weighs	...	526·2 grains
making a difference of	...	43·0 grains

for the 40 deg. under the same atmospheric pressure, viz., 30 inches of mercury.' (Blue Book, pp. 5, 6.) This difference in weight produces a speed of at least 10 ft. per second, in ordinary flues or chimneys. (For demonstration see 'Health and Comfort,' p. 107, *et seq.*)

dangerous current, because with this speed the air would be passed into and through the wards at a rate to replenish them every four minutes.

"This would, of course, be too rapid movement of the air through the wards, and would be felt as a draught; it would therefore have to be checked by partially closing the ward inlets, or preferably the outlets, so as to reduce the speed at least one half, because the wards ought not to be emptied and replenished oftener than every twenty minutes.

Natural Forces.

"If, therefore, the inlets and outlets be properly proportioned and open, and there be free passage for the air up through the hospital, the ordinary atmospheric pressure will carry on the ventilation quite efficiently, and the whole hospital will be kept fresh and comfortable by the natural forces alone.

"There is no fear that the speed will not be enough to keep up efficient ventilation; it is more likely to be too great, but there need be no fear of its being too great, because it is completely under control, and can be regulated to any rate desired by the valves at the ward inlets and outlets; or be arrested altogether by the shutters at the primary and secondary inlets. In order to ensure this ample ventilation, however, both inlets and outlets must be open; if the inlets be closed the heavy outside air will press its way through the outlets, and there will be down-draught, at any rate if fires are causing draught up the chmneys.

"If the outlets be closed the air will have difficulty in entering at the inlets, even though these be wide open, because if the air cannot get out, it will not come in. In either case there will be stagnation, discomfort, and unhealthiness; that is, unless there are fires to prevent these untoward results, which in summer there will not be, nor will there be in winter either, if the wards are warmed by heated pipes.

"In spring and autumn the difference in weight may average not more than between air at 45 deg. and 65 deg. F., but this will produce a speed of about 6 ft. per second, and with it an ·8 in. square outlet will be capable of giving passage to all the air of a single-bed ward in nine minutes, which is still too rapid; but, in this instance, as in the others, it can be diminished to the required twenty minutes by the valves and shutters, the regulation of which will be a matter of very little trouble, not more than the opening and closing of windows.

"*Spontaneous*" *Ventilation.*

"The plan here sketched out is, in its main features, natural or 'spontaneous' ventilation. Natural ventilation is certainly much to be preferred to any and every artificial system, whether on the plenum or vacuum principle, and it is, of course, much less complicated. It is, indeed, comparative simplicity itself — merely arranging openings and warming the air, and, as shown above, it acts more than efficiently.

"It also involves very little original outlay, and comparatively no permanent cost for maintenance. Whereas all artificial systems involve costly original plant of machinery, as well as heavy permanent expense for maintenance in engines, engineers, fuel, &c., and with all they cannot be made as efficient or nearly so pleasant and healthy in operation.*

Requirements of the Government Commissioners.

"The foregoing plan of ventilation and warming meets all requirements of the writer in the 'Encyclopædia Britannica,' and most of those of the

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* "It will, I think, be admitted by all who are familiar with dynamics that when the external temperature is below 30 deg. F., and the interior of the hospital is above 60 deg. F.—which difference produces a speed of about 8 ft. per second—by letting in the outer air at the basement and giving it free passage up through the hospital and out through the ceilings of the wards, the movement of the air through the wards will be quite rapid enough to ensure efficient ventilation, without mechanical help of any kind; that indeed it will be too rapid, notwithstanding the obstruction by inevitable friction during its passage through the hospital.

"During some days in spring and autumn, and generally in summer, the actual difference between the outside and inside air may not be more than 20 deg. or 15 deg., but even then the speed will be over 4 ft. per second. Even in the hot sultry days of summer, when the atmosphere is comparatively still, the bodies and respiration of the patients, being over 98 deg. F., will raise the temperature of the air surrounding them sufficiently to cause it to rise and move upwards away from them, and more so if air at a lower temperature is at the same time moving into the ward to take its place, consequently, if the outside air entering at the basement and being there cooled by ice, is passing up through the corridors and into and through the

Government Commissioners and of the authors of 'Health and Comfort in House Building'; and it is easy to perceive that it will act as well at night as in the daytime, and in winter as in summer; that it is equally applicable to few wards or many, to large hospitals and small, and to general hospitals as well as special; also that ample currents of cold air may be rushed through the whole hospital or through separate

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wards, more movement of the air of the wards – that is, more ventilation will be effected in the hot days of summer without open windows than with them (see 'Health and Comfort,' pp. 19, 20), because open windows themselves, even on both sides of the ward cannot *cause* 'ventilation' in the proper sense of the word; that is, cannot cause the air to move either into or out of the ward.

"Some better provision than open windows is necessary for ventilation when the outer air is motionless, some provision that will cause a difference in the temperature, and therefore in the weight of the outside and inside air, and so cause it to move. For these—in this country—rare occasions ice placed near the primary inlet is much preferable to the original outlay and the permanent cost of motive power by fans.

"I am aware that some medical practitioners do recommend hospitals to be ventilated only by open windows on both sides of large wards, even in winter in this climate, and maintain that there is neither risk nor discomfort in doing so. They do not themselves, however, submit to such ventilation; that is, they do not themselves sit in their study, or have their families to sit in the morning room or sleep in bedrooms with windows to the east open all the winter through! And it is only bounce for matrons and nurses to acquiesce in such an arrangement and uphold it; they are themselves not stories or individual wards by the windows alone, and yet be completely under control;—regulated or stopped at pleasure; and that the same may be accomplished from the bottom upwards to the top by the special inlets and outlets alone, and in this case also it can be regulated and controlled, or arrested altogether; also that in cold weather the same may be accomplished with air warmed by the

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confined to beds underneath open windows, but are moving about in and out of the wards. Nor do they submit to it in their own rooms during cold easterly windy days and nights.

"The helpless patients scarcely dare complain or even admit that they feel a draught if the nurse says they do not. Nor perhaps do they suffer very greatly from it whilst tucked up in blankets, except in pulmonary ailments; but what about when they have to sit up or get out of bed at night under an open window at Christmas? For consumptive patients this would be both distressing and dangerous; in this country they are not in hospital to be 'Davosed' but for comfort and protection, and for the treatment of complications.

"Some doctors are, however, beginning to treat consumptives with open windows at all times, night as well as day, and winter as well as summer; and in all weathers, frost and snow and wind and storm too, that is, 'fresh air' at all risks. This will perhaps afford them a better chance than do foul unventilated apartments, whether private or hospital, but it is 'kill or cure' treatment.

"The Government Commissioners enter very fully and elaborately into the necessities for ventilation and warming, and into the causes of the failure of the ordinary methods, especially those by open fires. They insist that the inlets shall let in only warmed air, and only at the lowest part of the room; and that the outlets shall give exit to the foul air at the highest part.

warming apparatus, and this also completely under control; also that in winter the incoming air may be warmed to almost any degree by the warming apparatus; and in summer cooled to almost any degree by ice being placed in the fresh air chambers; also that the air, as well as being dried and filtered, may be disinfected, medicated or perfumed at pleasure, before passing into the hospital."

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